Institutional COF Prioritization: Risk Based or Lottery?

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Objectives of this Presentation

- Ensure common understanding of risk
- Examine NASA guidance
- Highlight guidance ambiguity
- Impact of ambiguity
- Implications to Prioritization process

Risk is Inevitable

"It is impossible to win the great prizes
of life without running risk"
Theodore Roosevelt

"The safest place for a ship is in a harbor.
But that is not what the ship was built for."

Therefore, risk must be understood, assessed and managed

Risk

- **The measure of the probability and severity of adverse effects.**
  Lowrance, "Of Acceptable Risk," 1976

- **A set of triplets that answer the questions:**
  1. What can go wrong? (accident scenarios)
  2. How likely is it (probabilities)
  3. What are the consequences? (adverse effects)
  Kaplan & Garrick, "Risk Analysis," 1981

- **Operationally defined as:**
  1. The **scenario(s)** leading to degraded performance with respect to one or more performance measure.
  2. The **likelihood(s)** of those scenarios.
  3. The **consequence(s)** severity of performance degradation that would result if those scenarios were to occur.
  - **Uncertainties** are included in evaluation of likelihoods & consequences.
  NPR 8000.4A

Risk Management

- The systematic method of identifying, analyzing, treating, and monitoring the risks involved in an activity or process.

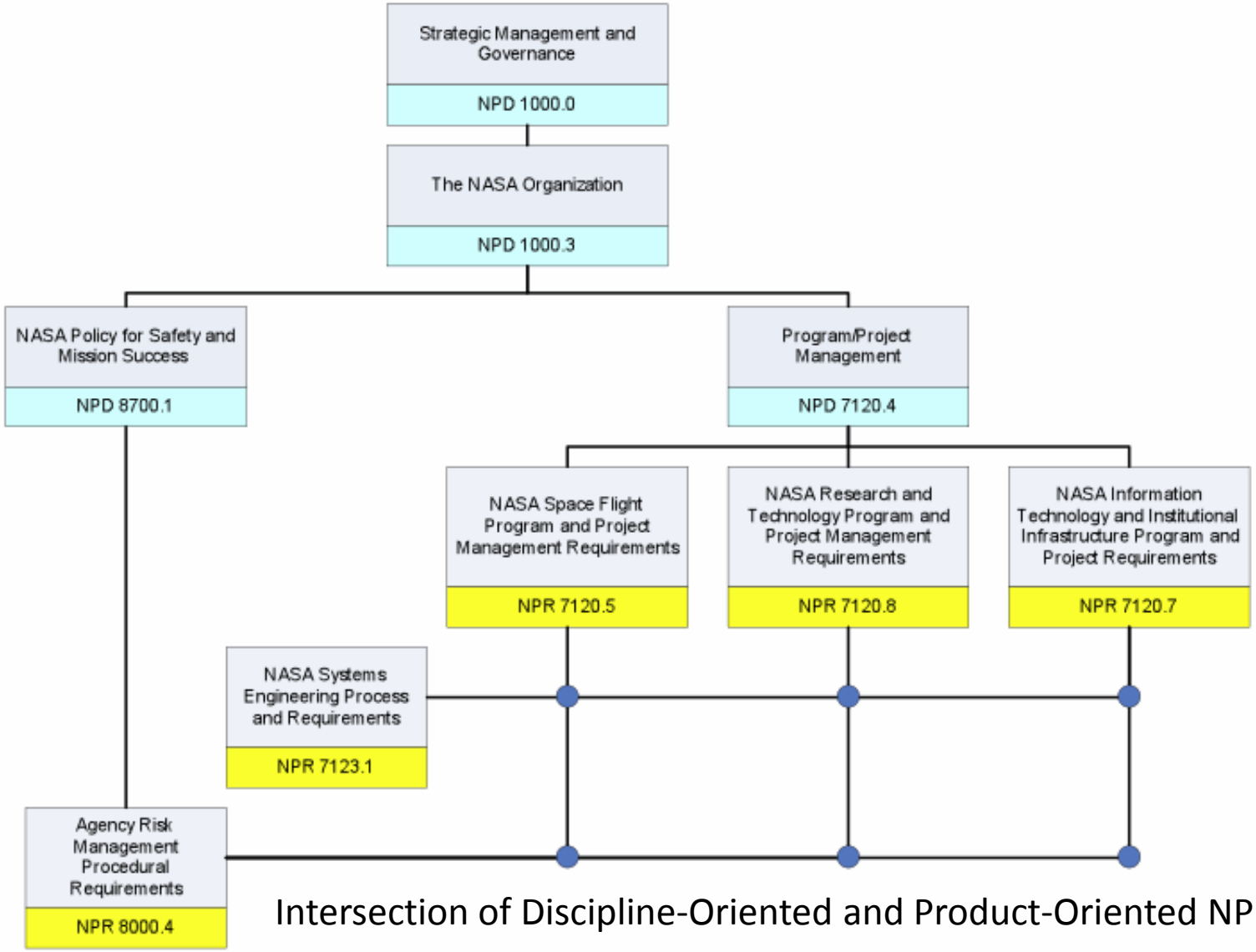
- Risk management is an operational philosophy that is applicable to almost all NASA activities/processes.

Importance of Probability

"It is remarkable that a science which began with the consideration of games of chance should become the most important object of human knowledge"

Pierre Simon, Marquis de Laplace, (1749-1827),
"Analytic Theory of Probabilities"

NASA Authority



Intersection of Discipline-Oriented and Product-Oriented NPRs

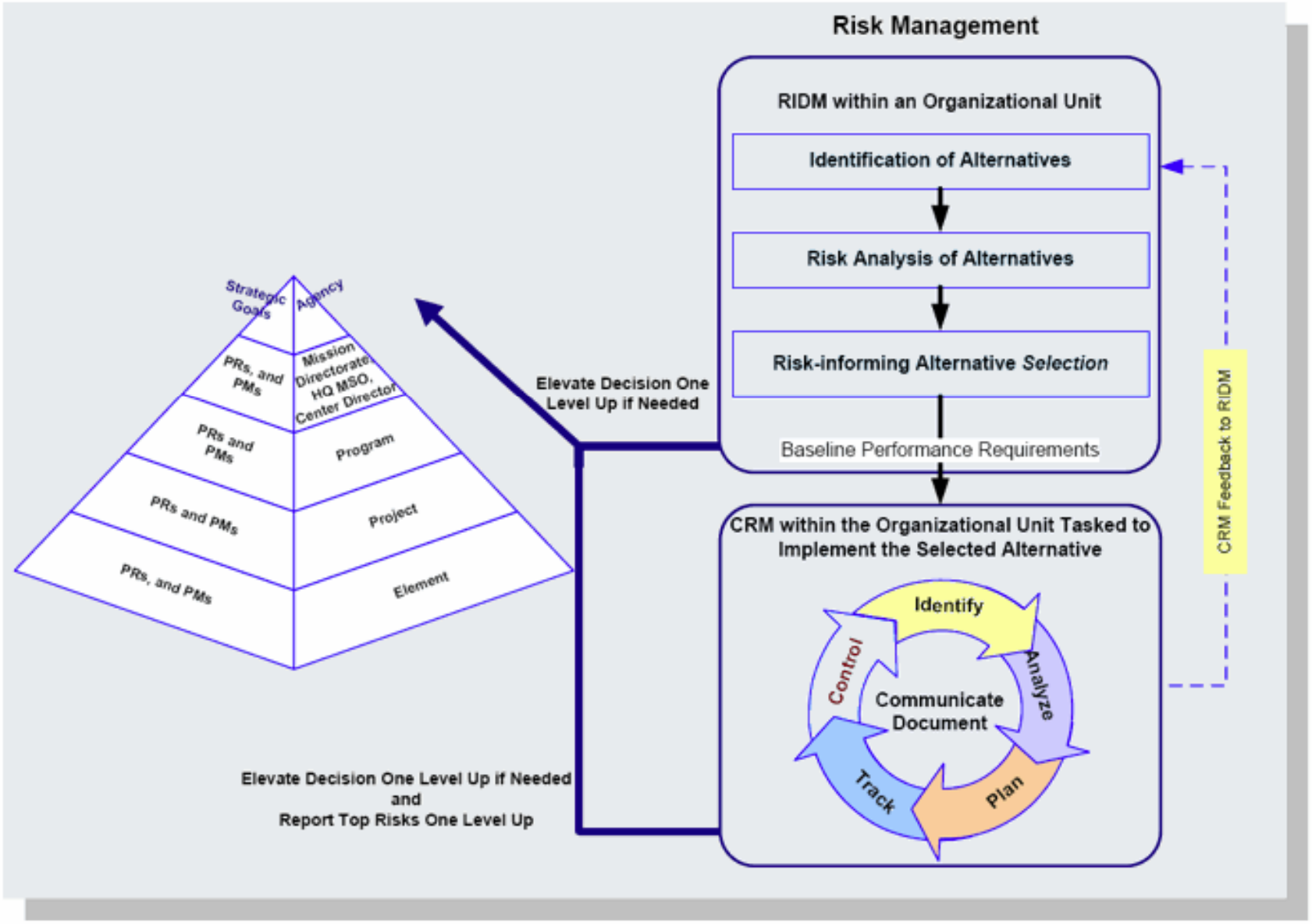
Applicable NASA Documents

- NPR 8000.4A – Agency Risk Management Procedural Requirements
  - NPR 8705.4 – Risk Classification for NASA Payloads
  - NPR 8705.5A – Technical Probabilistic Risk Assessment (PRA) Procedures for Safety and Mission Success for NASA Programs and Projects
    - NASA SP-2010-576, NASA Risk-Informed Decision Making Handbook
  - Office of Strategic Infrastructure (OSI) Risk Management Plan (RMP)

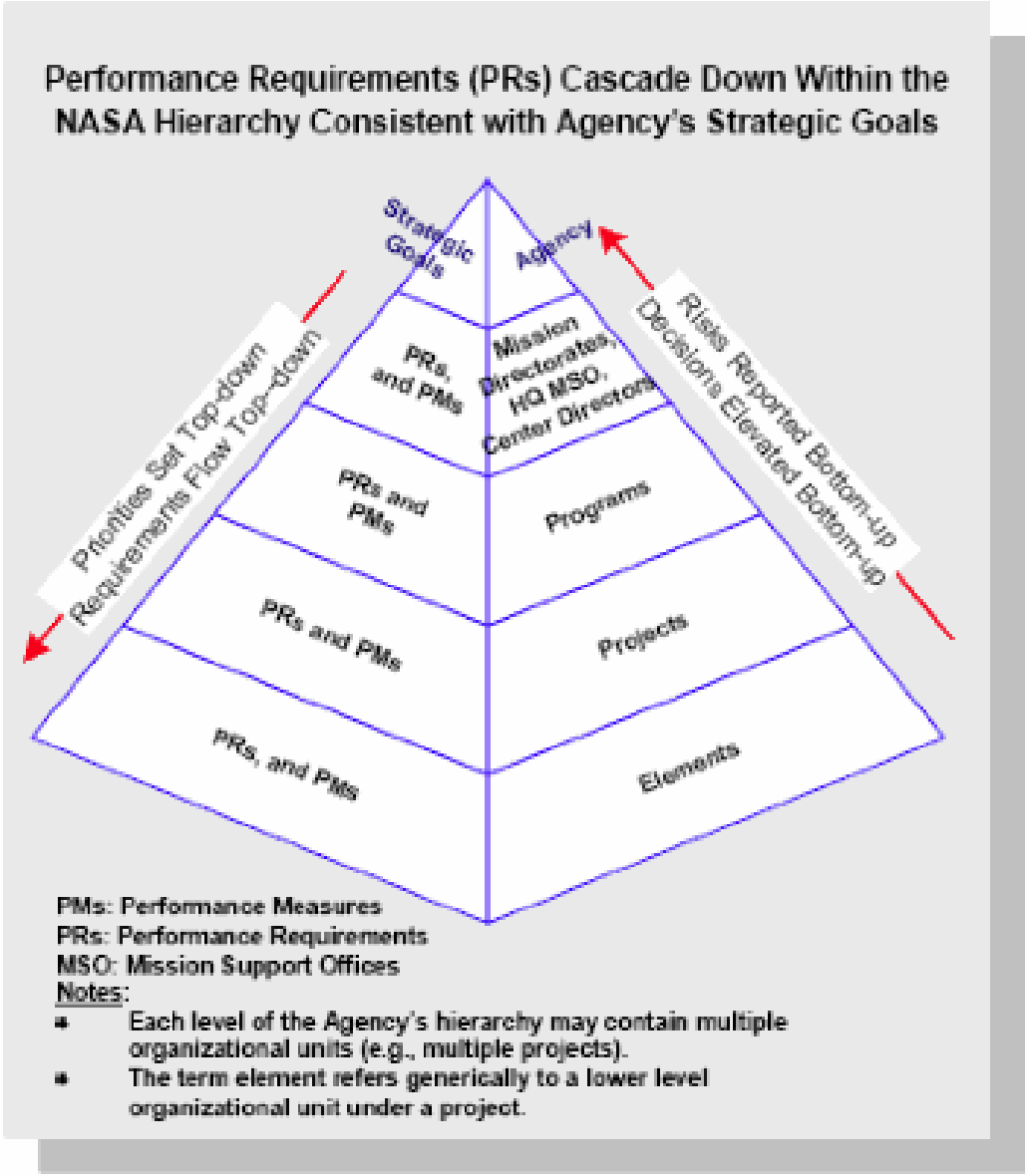
- NPR 7120.7 – NASA Information Technology and Institutional Infrastructure Program and Project Management Requirements
  - NPD 8820.2 – Facility Project Implementation Guide

NOTE: Institutional COF prioritization based on OSI RMP definitions

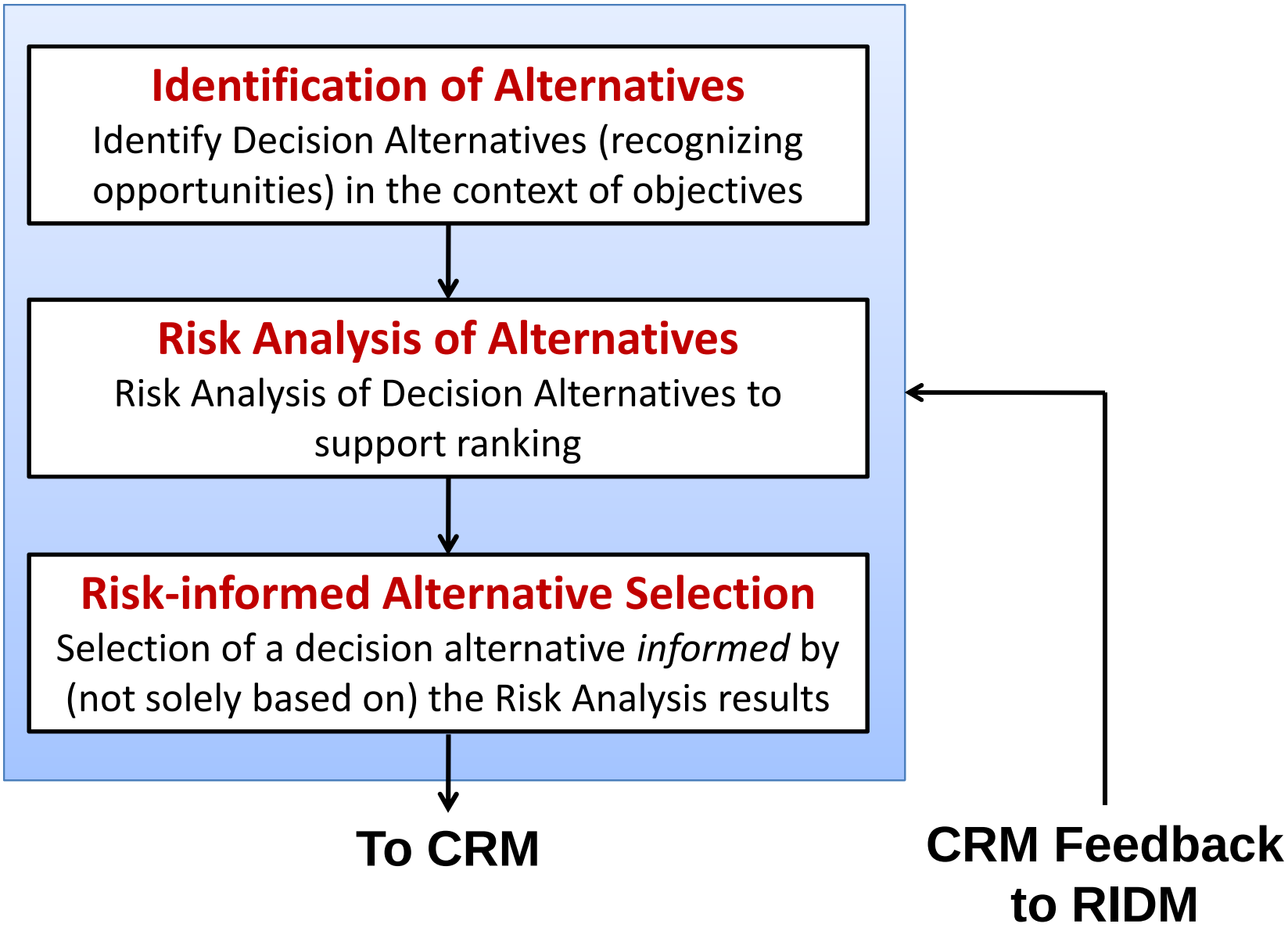
NASA Risk Management Framework, 8000.4A



Flow of Requirements & Decisions



Risk Informed Decision Making (RIDM)



Continuous Risk Management (CRM)

Program/project constraints, hazard analysis, FMEA, FTA, lessons learned →

IDENTIFY
Identify contributors to risk

→ Statement of risk, List of risks

Risk data: test data, expert opinion, PRA, technical analysis →

ANALYZE
Evaluate (impact/severity, probability, timeframe), classify, prioritize risks

→ Risk evaluation
Risk classification
Risk prioritization

Resources →

PLAN
Decide what, in anything, should be done about risks

→ Risk mitigation plans
Risk acceptance rationale
Risk tracking requirements

Program/Project data (metrics information) →

TRACK
Monitor risk metrics and verify/validate mitigation actions

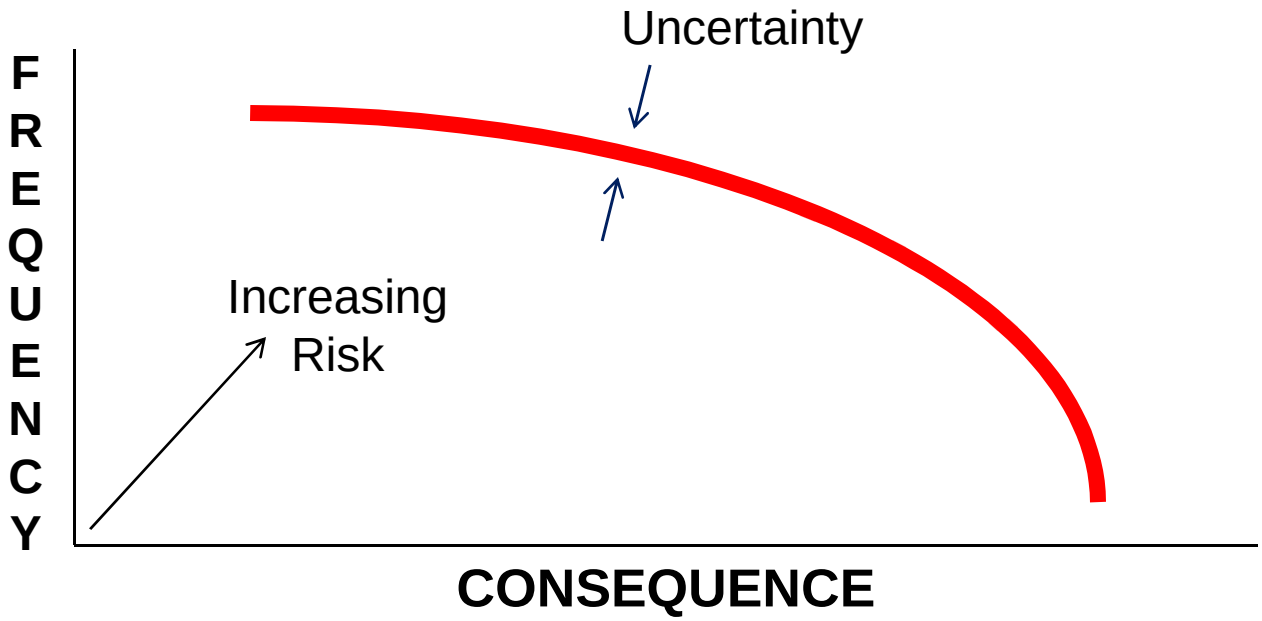
→ Risk status report on:
- Risks
- Risk mitigation plans

CONTROL
Replan mitigations, close risks, invoke contingency plans

→ Risk decisions

Communication & documentation extend throughout all functions

Risk Curve



Risk Key Concepts, 8000.4A

Components:

- **Scenario(s)** - leading to degraded performance with respect to one or more performance measure (e.g., scenarios leading to injury, fatality, destruction of key assets; scenarios leading to exceedance of mass limits; scenarios leading to cost overruns; scenarios leading to schedule slippage);

- **Likelihood(s)** - (qualitative or quantitative) a measure of the possibility that scenario will occur.
  - In terms of probability, based on frequency or timeframe.

- **Consequence(s)** - (qualitative or quantitative severity of the performance degradation) that would result if the scenario(s) was (were) to occur.

Risk Key Concepts, 8000.4A Con't

- **"Performance Measure"** – metric to measure the extent to which a system, process, or activity fulfills its intended objectives.
  - **Safety** – (e.g., avoidance of injury, fatality, or destruction of key assets),
  - **Technical** – (e.g., thrust, output, amount of observational data acquired),
  - **Cost** – (e.g., execution within allocated cost),
  - **Schedule** – (e.g., meeting milestones).

- A **complete characterization** of the scenarios, likelihoods, and consequences also calls for characterization of their uncertainty

Responsibilities, 8000.4A

- **Mission Directorates** – responsible for management of programmatic risks within their domains and are responsible for elevating risks to the Management Councils at the Agency level as appropriate.

- **Center Directors** – responsible for management of institutional risks at their respective Centers.

- **HQ Mission Support Offices** – responsible for management of Agency-wide institutional risks.

- **Program/Project Managers** – responsible for program and project risks within their respective programs and projects.

OSI RMP Key Concepts

- **Risk Identification**
  - Risk Statement
  - Risk Context
  - Risk Approval and Validation
- **Risk Analysis**
  - Likelihood (Probability) and Consequence (Impact)
  - Risk Exposure
  - Risk Prioritization
  - Timeframe
- **Risk Planning**
  - Assign Responsibility
  - Determine Strategy

OSI RMP Risk Statement

"Given the **Condition**; there is a possibility that the **Consequence** will occur."

Condition – a single phrase that identifies possible future problems, and describes current key circumstances, and situations that are causing concern, doubt, anxiety, or uneasiness.

Consequence – a single phrase or sentence that describes the key negative outcome(s)

OSI RMP Risk Context, Analysis

Risk Context – The Context captures the what, when, where, how, and why of the risk by describing any circumstances, contributing factors, regulatory factors, related issues, background, and any other information not contained in the risk statement that would help in understanding the risk.

Risk Analysis - Risks are characterized by the combination of the likelihood (probability) that OSI or other mission activity will experience an undesirable event and the consequence (impact) or severity of the undesired event, were it to occur.

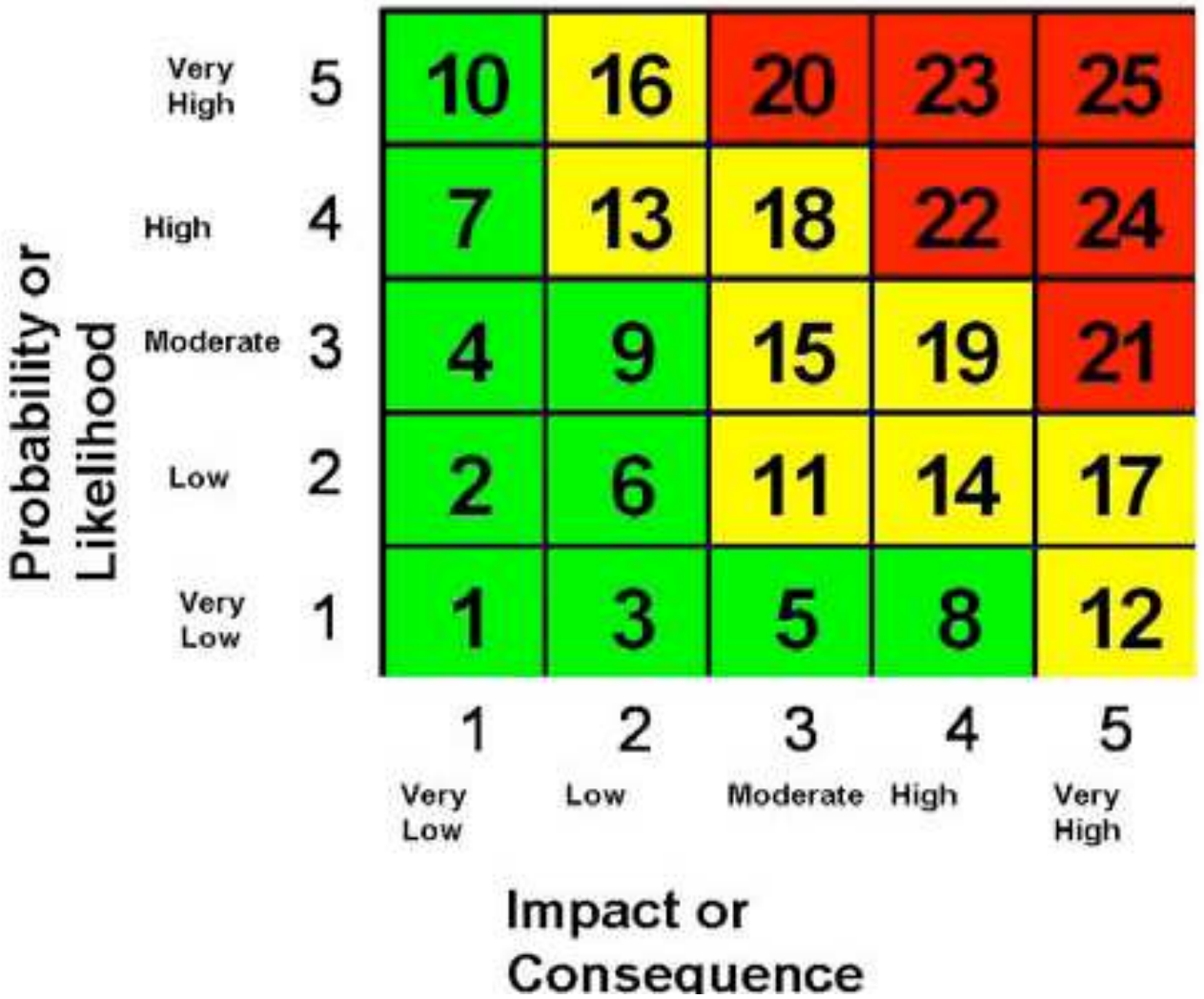
OSI RMP Consequence of Occurrence

IMPACTS TO I&A GOALS	Consequence Rating	Very Low	Low	Moderate	High	Very High
	LEVEL	1	2	3	4	5
	SAFETY	Magnitude of harm or discomfort to employees, contractors, or public is not greater than ordinarily encountered in daily life --Or-- Negligible damage to asset consistent with normal wear and tear	Minor first-aid treatment (does not adversely affect personal safety or health) --Or-- Minor loss/damage to agency capabilities, resources or assets --Or-- Administrative regulatory non-compliance (scoped to safety, health and environment)	Medical treatment for a injury or incapacitation --Or-- Moderate loss/damage to agency capabilities, resources or assets --Or-- Moderate regulatory non-compliance (scoped to safety, health and environment)	Severe injury or incapacitation --Or-- Major loss/damage to agency capabilities, resources or assets --Or-- Major regulatory non-compliance (scoped to safety, health and environment)	Death or permanent disability --Or-- Complete loss of critical agency capabilities, resources or assets
	PERFORMANCE	Nuisance. No impact on mission support objective --Or-- No loss of institutional capability --Or-- Non-compliance with internal policy and procedures -- No corrective action or modification is needed	Minor impact on mission support goals --Or-- Minor loss of institutional capability --Or-- Administrative regulatory non-compliance -- Mild corrective actions or slight modifications are needed to achieve mission support goal, to maintain institutional capability, or remedy non-compliance	Moderate impact on mission support goals --Or-- Moderate loss of institutional capability --Or-- Moderate regulatory non-compliance -- Corrective actions or modifications are available to achieve mission support goal, to maintain institutional capability, or remedy non-compliance	Major impacts to mission support goals -- Or -- Major loss of institutional capability --Or-- Major regulatory non-compliance -- Corrective actions or modifications may be technically feasible. support goal, institutional capability, or non-compliance remedy cannot be achieved through available resources or time constraints.	support goals are not achievable --Or -- Complete loss of critical institutional capability
	SCHEDULE	Negligible impact with slight schedule adjustments. Impact can be compensated by available schedule with no change of end date (e.g., 1 month delay to major project milestones)	Negligible impact with slight schedule change. Impact cannot be compensated by available schedule and impacts end date (e.g., 1 to 3 month delay to major project milestones)	Moderate overall schedule impact (e.g., >3 month delay to major project milestone --Or-- 1 month delay to major program milestone)	Major overall schedule impact (e.g., 1 to 3 month delay to major program milestone)	Unable to achieve key/major milestone (e.g., >3 month delay to major program milestone)
	COST	Impact of < 0.1% to functional/project budget --Or-- < $40K impact	Impact of > 0.1% and < 1% to functional/project budget --Or-- > $40K and < $400K	Impact of > 1% and < 10% to functional/project budget --Or-- > $400K and < $4M	Impact of > 10% and < 25% to functional/project budget --Or-- > $4M and < $10M	Impact of > 25% to functional/project budget --Or-- > $10M

OSI RMP Likelihood of Occurrence

LIKELIHOOD	LIKELIHOOD RATING		
	1	Very Low	Qualitative: Very unlikely to occur, management not required in most cases. Strong controls in place. Quantitative: <= 5% (for risks with primary impact on Cost, Schedule, or Performance) or <=E-5 (for risks with primary impact on Safety)
	2	Low	Qualitative: Not likely to occur, management not required in all cases. Controls have minor limitations/uncertainties. Quantitative: <= 10% (for risks with primary impact on Cost, Schedule, or Performance) or <=E-4 (for risks with primary impact on Safety)
	3	Moderate	Qualitative: May occur, management required in some cases. Controls exist with some uncertainties. Quantitative: <=33% (for risks with primary impact on Cost, Schedule, or Performance) or <=E-3 (for risks with primary impact on Safety)
	4	High	Qualitative: Highly likely to occur, most cases require management attention. Controls have significant uncertainties. Quantitative: <=50% (for risks with primary impact on Cost, Schedule, or Performance) or <=E-2 (for risks with primary impact on Safety)
	5	Very High	Qualitative: Nearly certain to occur, requires immediate management attention. Controls have little or no effect. Quantitative: <100% (for risks with primary impact on Cost, Schedule, or Performance) or <=E-1 (for risks with primary impact on Safety)

OSI RMP Risk Exposure



OSI RMP Timeframe

T I M E F R A M E	Immediate	Mitigative action(s) needs to take place within next 90 days or NASA will be impacted by risk.
	Near-term	Mitigative action(s) needs to take place within next 3 months to 1 year or NASA will be impacted by risk.
	Mid-term	Mitigative action(s) needs to take place within next 1 to 3 years or NASA will be impacted by risk.
	Long-term	Mitigative action(s) needs to take place within next 3 to 6 years or NASA will be impacted by risk.
	VSE	Mitigative action(s) needs to take place within next 6 to 30 years or NASA will be impacted by risk.
	On-going	This risk becomes a problem with regular frequency. Mitigative action(s) will reduce the frequency and impacts of this risk

Timeframe is the period when action is required, not when the risk will occur!

OSI RMP Strategy

- Research
- Accept
- Watch
- Mitigate
- Transfer

8000.4A – OSI RMP Comparison

8000.4A

- **Scenario** – leading to degraded performance with respect to one or more performance measure;
- **Likelihood** – of the scenario (qualitative or quantitative);
- **Consequence** – that would result if the scenario were to occur (qualitative or quantitative severity of performance degradation).
- Complete **characterization** of scenarios, likelihoods, & consequences calls for characterization of their **uncertainty**

OSI RMP

- **Statement** – "Given the **Condition**; there is a possibility that the **Consequence** will occur."
- **Condition** – a single phrase that identifies possible future problems, and describes current key circumstances, and situations that are causing concern, doubt, anxiety, or uneasiness.
- **Consequence** – a single phrase or sentence that describes the key negative outcome(s)
- **Risk** – characterized by the combination of the **likelihood** that an OSI or other mission activity will experience an undesirable event and the **consequence** or severity of the undesired event, were it to occur (5x5).

Issues

- **OSI RMP not fully consistent with 8000.4A**
  - Inconsistencies with “Likelihood” and “Consequence”
    - RMP Likelihood of “Undesirable Event” not linked to Performance Measure
    - RMP Consequence both Qualitative/Quantitative Rating, and Narrative
    - Qualitative/quantitative in 8000.4A, qualitative in RMP (Risk Statement)
  - 8000.4A Scenario not equivalent to RMP Risk Statement & Risk Context
  - Causality explicit in 8000.4A; ambiguous in RMP

- **Results in inadequate discrimination for risk-based prioritization**
  - “Unlinked” Likelihood & Consequence
  - Ambiguity – Likelihood of Initiating Event or Likelihood of Scenario
  - Risk Exposure (5x5) Subjectivity
  - Inadequate/no consideration of probabilities

Causality

- **Causality is the relationship between an event (the cause) and a second event (the effect)**
  - Root Cause Analysis
  - Fault Tree Analysis
  - Failure Modes and Effects Analysis
  - Probabilistic Risk Assessment
- **Deterministic vs. Probabilistic Causation**
- **Necessary vs. Sufficient vs. Contributing Causes**
- **Explicit in 8000.4A; ambiguous in OSI RMP**
- **Causality may impact Risk Exposure**

Example – Without Causality

Risk Context:

"For the want of a nail, the shoe was lost.
For want of a shoe, the horse was lost.
For want of a horse, the rider was lost.
For want of a rider, the battle was lost.
For want of a battle, the kingdom was lost,
And all for the want of a horseshoe nail."

Corresponding Risk Statement:

"Given that there is a shortage of horseshoe nails,
there is a possibility that the kingdom will be lost."

Risk Exposure Score: 25

Example – With Causality

Risk Context – "the Scenario:"	Probability
Horseshoe nail shortage	1.0
"For the want of a nail, the shoe was lost.	0.5
For want of a shoe, the horse was lost.	0.5
For want of a horse, the rider was lost.	0.5
For want of a rider, the battle was lost.	0.5
For want of a battle, the kingdom was lost,	0.5
And all for the want of a horseshoe nail."	

Corresponding Risk Statement(s):

"Given that there is a shortage of horseshoe nails, there is a 3.125% probability that the kingdom will be lost", or numerous others…..

Does low probability of the consequence occurring still warrant a Risk Exposure Score of 25?

Implications to Prioritization Process

What Would Change

- **Base Institutional COF Prioritization on 8000.4A Guidance**
  - Update OSI RMP for consistency with 8000.4A
  - Resolve inconsistency with Likelihood, Consequence & Scenario

- **Enforce Causality**
  - Resolve “unlinked” Likelihood & Consequence
  - Consider Likelihood of Initiating Event(s) **AND** Likelihood of Scenario

- **Perception of Scenario**
  - Probabilistic rather than deterministic
  - Quantify Likelihood/Consequence/Uncertainty where appropriate

Implications to Prioritization Process

Institutional COF Prioritization Risk Exposure Based On:

COMPONENT	QUESTIONS TO ANSWER
Scenario (narrative)	What can go wrong?
	What happens when things go wrong?
Likelihood (rating)	What are the probabilities of things gong wrong?
Consequence (rating)	What is the consequence of things going wrong?
Uncertainty (rating/narrative)	What are the uncertainties and how do they affect the estimate of consequences and probabilities?
Mitigation	What can we do to prevent things from going wrong, or reduce the severity of the consequence?

Implications to Prioritization Process

Methodology (Using Probabilistic Risk Assessment)

COMPONENT	STEPS
Scenario (narrative)	**Identify At-Risk Performance Measure** – Safety, Technical, Cost, Schedule.
	Identify Initiating Event(s) – Those that may lead to risk becoming reality.
	Identify Sequence(s) of Failure – The combination(s) of multiple failure(s) after Initiating Event that must occur for a risk to become reality (causality).
Likelihood (rating)	**Estimate Frequency of Each Initiating Event** – Use maintenance data, etc…
	Estimate Probability of Each Sequence – Use probabilistic theory.
	Estimate Likelihood of Each Sequence – Multiply sequence probability by the frequency of the relevant initiating event.
	Rate the Likelihood – Based on evaluation of the likelihoods of all individual sequences. Quantitative or qualitative, use OSI RMP Likelihood Rating table.
Consequence (rating)	**Rate the Consequence** – Impact, if the risk becomes reality. Quantitative or qualitative, use OSI RMP Consequence Rating table.
Uncertainty (rating/narrative)	**Estimate Impact of Uncertainty** – Likelihood rating is typically based on a distribution of values. Uncertainty is the “width” of the distribution curve.
Mitigation	**Select Mitigation Strategy** – Reduce either/both Likelihood, Consequence

Implications to Prioritization Process

Concluding Thoughts

- **Results in greater Risk Exposure (5x5) discrimination**
- **Eliminate need for "Discerning Factors"**
- **Concerns with implementing into current COF cycle**
  - Significant learning curve
  - Implement "risk light"?
- **May require training**
  - Probability & statistics
  - FTA, FMEA, PRA, etc…
- **Does it work both ways?**
- **Impact on Prioritization Process**

Discussion/Questions

Is anybody awake?